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REVIEW ARTICLE

# Phytosociology of the shrub-arboreal stratum of the Ibura National Forest, Northeastern Brazil: are 35 years sufficient to promote the regeneration of a forest fragment?

# Fitossociologia do estrato arbustivo-arbóreo da Floresta Nacional do Ibura, Nordeste do Brasil: 35 anos são suficientes para promover a regeneração de um fragmento florestal?

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## Abstract

Among the various applications of phytosociology, the evaluation of natural regeneration is of great importance, mainly because it provides insights for ecological restoration. The objective of this study was to analyze the composition and phytosociological parameters of shrub and tree vegetation in areas

of plantation of eucalyptus (*Corymbia citriodora*) and areas of native forest in the Ibura National Forest, located in the Sergipe state of northeastern Brazil. For this purpose, 20 plots were sampled and all individuals with a diameter at breast height (DBH) ≥ 8 cm were measured. Sampling revealed 821 individuals in the forest area and 1,000 in the eucalyptus area. These individuals represent 84 species and the areas presented a significant difference in species composition, with 61 in the eucalyptus area and 65 in the Forest area, and only 40 species were common to both areas. There was a predominance of pioneer individuals in the eucalyptus area. There also was a significant difference in basal area, relative density and relative dominance, but no significant differences were observed in average height. It was concluded that a period of 35 years is insufficient for the recovery of the eucalyptus area, which remains in a more initial successional stage than the forest area.

**Resumo**

Entre as várias aplicações da fitossociologia, a avaliação da regeneração natural possui grande importância, principalmente porque fornece subsídios para restauração ecológica. Diante disso, este trabalho foi realizado com o objetivo de analisar a composição e os parâmetros fitossociológicos da vegetação arbustivo-arbórea em áreas de plantio de eucalipto (*Corymbia citriodora*) e de mata nativa na Floresta Nacional do Ibura, no estado de Sergipe. Para esta finalidade, foram demarcadas 20 parcelas e amostrados todos os indivíduos com diâmetro à altura do peito (DAP) ≥ 8 cm. A amostragem revelou 821 indivíduos na área de mata e 1.000 para a área de eucalipto. Esses indivíduos representam 84 espécies e as áreas apresentaram diferença significativa na composição de espécies, sendo 61 na área de eucalipto e 65 na área de floresta, e apenas 40 comuns a ambas as áreas. Observamos o predomínio de indivíduos de espécies pioneiras na área de eucalipto. Também encontramos diferença significativa para a área basal, densidade relativa e dominância relativa, mas não foram observadas diferenças significativas quanto à altura média. Conclui-se que o período de 35 anos não foi suficiente para a recuperação da área de eucalipto, a qual ainda se encontra em estágio sucessional mais inicial que a área de mata.

**Keywords**

Atlantic Forest, dispersion syndrome, ecological groups, eucalyptus settlements, sub-forest

**Palavras-chave**

Floresta Atlântica, Grupos ecológicos, Povoamentos de Eucalipto, Síndromes de dispersão, Sub-bosque

## Introduction

Phytosociological studies are fundamental to analyze the structure and composition of plant communities, allowing a better understanding of the relationships between plants. In these studies, it is also possible to evaluate the distribution pattern, the importance and the ecological groups of the species in order to identify the successional stage of the community, which in turn can be indicative of conservation status (Freitas and Magalhães 2012; Chaves et al. 2013).

Many authors emphasize the importance and necessity of studying the many applications of phytosociology in the evaluation of natural regeneration. This evaluation assumes great importance given the necessity of information on the restoration of native vegetation, particularly for the sub-forest of exotic-homogeneous settlements and of fast growth such as eucalypt (Calegario et al. 1993; Tabarelli et

al. 1993; Sartori et al. 2002). Recent studies on the natural regeneration show that native plants can regenerate even in impacted sites, such as sites with eucalyptus plantations. Thus, native species contribute better to local resilience and can recover a significant portion of biodiversity. It is estimated that up to 140 native species with high regenerative capacity occur in the sub-forest of these plantations (Onofre et al. 2010; Viani et al. 2010). Faced with these observations and the fragmentation and destruction of natural forests, several proposals have arisen on the use of Eucalyptus species in the restoration of degraded areas (Sartori et al. 2002; Viani et al. 2010).

Although abandoned eucalyptus plantations may have good recolonization rates, it is important to understand which native species are critical to recovering these degraded sites. Further studies are needed to investigate the real contribution of native species to the natural regeneration of these sites. For instance, not all native species can colonize areas containing eucalyptus, because *Corymbia citriodora* generates changes in natural habitat conditions, and thus may cause limiting barriers to the establishment of native species, such as: i) the high frequency of light that inhibits arrival of secondary species; ii) the allelopathic effect of *C. citriodora*; and iii) the desertification caused by deforestation (Fonseca et al. 2009; Evaristo et al. 2011).

Little is known about how many areas can be permeable to the arrival of species and how long it takes for their structural recovery. However, some authors indicate that the success of the rapid recovery of the natural vegetation in these eucalyptus sub-forest areas has been associated with the proximity of a source of propagules and the maintenance of the seed bank (Calegario et al. 1993; Fonseca et al. 2009; Onofre et al. 2010).

Most of the studies on natural regeneration in the sub-forest of homogeneous exotic plantations are concentrated in the southeastern region of Brazil, especially in the states of Minas Gerais and São Paulo (Viani et al. 2010). In Sergipe, there are still no studies of natural regeneration in the sub-forest of these plantations, in addition to the existence of gaps in the structuring of plant communities. Currently the state of Sergipe has approximately 6,153 hectares of available areas for planting of exotic homogeneous species. Only in 2018 there was an increase of 42% (2,573 hectares) in the expansion of areas intended for this activity (IBGE 2019).

In Sergipe, the cultivation of *Corymbia citriodora* is attracted by the increased demand; it presents good profitable results derived from the varied uses of the plant (Evaristo et al. 2011). This exotic species has pioneer characteristics, showing easy adaptation to the Brazilian climate and rapid growth even under critical scenarios, such as poor soils. At the same time, it has characteristics of invasive species with potential allelopathic effect. Its height and small expansion of the crown together with the quality of the wood contribute to the interests of cultivation (Schneider 2003). Ecologically, its function is limited to overstock, carbon stock and shelter use for the fauna, since their dry and autochoric fruits cannot be consumed.

Among the conservation units in Sergipe lacking in phytosociological studies, is the National Forest (FLONA) of Ibura; it has a history of disturbance, being partially deforested for eucalypt plantation of the exotic species *Corymbia citriodora* and

remained unchanged. After 35 years of abandonment of this area of *C. citriodora* and its subsequent secondary succession, it is necessary to evaluate its current state of regeneration. For that, we will use a preserved area as a basis to illustrate how far the degraded area is from restoration. This information will be fundamental for the evaluation of the development of the sub-forest in the presence of *C. citriodora*, contributing to the gaps in recolonization of natural forest areas, which have been cleared for cultivation of exotic species.

Considering the above, the objective of this study was to compare the composition and structure of two forest fragments, one in a managed area (*C. citriodora* planting) and another in an unmanaged area to understand the effect of management on natural regeneration, in the Ibura FLONA, in the state of Sergipe, in northeastern Brazil. Finally, we compared the results obtained between the two areas to evaluate if 35 years was sufficient to promote the recomposition of the forest structure (species composition, stratification and proportion of dispersion syndromes and ecological groups) in a similar way as the native forest.

## Material and methods

### Study area

The study area is located in the municipality of Nossa Senhora do Socorro, in the state of Sergipe, northeastern Brazil. The Ibura FLONA (37°08'03"W, 10°50'19"S) is located in the sub-catchment area of the Cotinguiba River, on BR-101, occupying an area of 144 ha. The vegetation of this FLONA is classified as semidecidual forest (Atlantic Rainforest domain), in moderate and advanced stages of regeneration, associated with small patches of mangroves (Fig. 1) (Brasil 2005).

In general, the vegetation of the Ibura National Forest is composed of two large sets of formation types: a preserved forest area and an area under regeneration. The preserved forest area shows a dense canopy in an advanced state of succession when compared to other subareas and has an extension of approximately 55.52 ha (38% of the total). The area under regeneration has an understorey in secondary succession mixed with old plantations of *C. citriodora*, the management of which stopped only 35 years ago. This area has an extension of 20.28 ha (20% of the total) and a history of anthropic pressure (Santana et al. 2017) (Fig. 1).

This Ibura FLONA also conserves 328 species of vascular plants, with 79 new occurrences for the state and the presence of *Catasetum uncatum* (Orchidaceae) in the category of "near threatened" and *Zanthoxylum unifoliolatum*, a recently described species in this genus (Groppo and Pirani 2017; Santana et al. 2017).

### Data collection

The following two sites were selected for the phytosociological survey: (i) preserved forest and (ii) forest in regeneration under stands of *Corymbia citriodora*. In total,

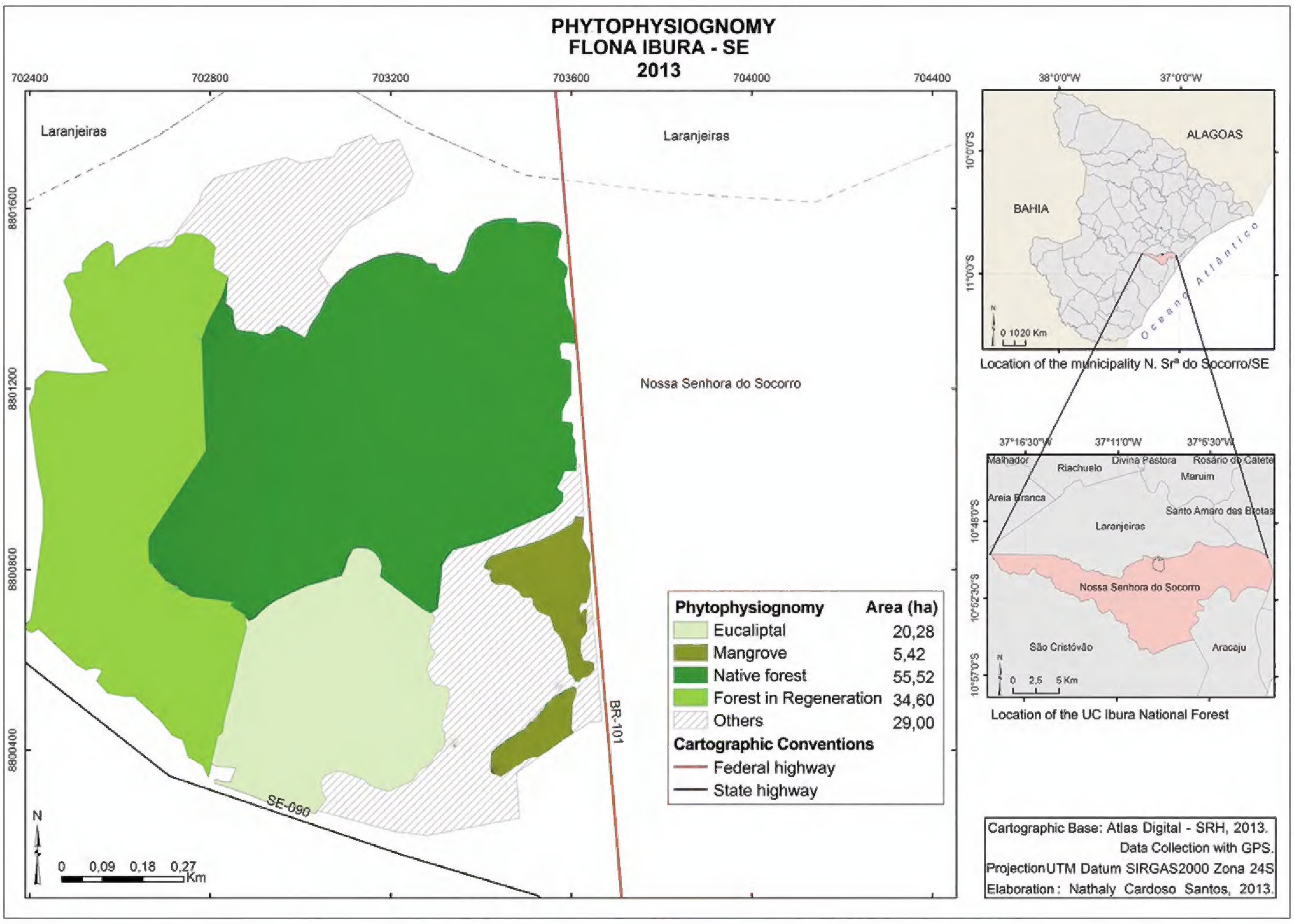


**Figure 1.** Characterization of vegetation and location of the study area, Ibura National Forest (FLONA), in the municipality of Nossa Senhora do Socorro, Sergipe, northeastern Brazil.

20 plots were demarcated, of which ten were distributed in each area, fixed with a size of 400 m$^2$ (20 × 20 m) totaling 8,000 m$^2$. The plots were distributed with distances between them of 50 m between the forest units and 35 m between these units of the eucalyptus area. All individuals with a diameter at breast height (DBH) ≥ 8 cm present in the plots were marked. Each of these individuals had their DBH and height measured (Felfili et al. 2011). The individuals of *C. citriodora* cultivated in the area in recovery also were included in the phytosociological analysis of the Ibura FLONA, excluding the dead standing individuals. All living individuals of the Arecaceae family were eliminated from the analysis since species of this family in the study sites, such as *Syagrus coronate*, have large stems and, in conjunction with the large number of individuals, would extract the value of the DBH for the areas.

Species identification was performed considering the material deposited in the herbarium ASE (Federal University Sergipe) after the floristic study conducted at Ibura FLONA by Santana et al. (2017).

## Data analysis

The successional stage of the studied areas was defined using a subjective criterion to classify species and individuals in ecological groups, according to the model suggested by Gandolfi et al. (1995) and Budowski (1965). For classification, we used the

observations made in the field and information present in the scientific literature on the species sampled in the area.

Classical phytosociological parameters were estimated only for living individuals, such as relative density, relative frequency, dominance, absolute dominance (total basal area), and the importance value index (IV). The parameters related to the vertical structure were also evaluated and the Shannon-Wiener diversity index and the Pielou equability (Mueller-Dombois and Ellenberg 2002; Oliveira and Amaral 2004; Felfili et al. 2011). Species that presented less than two individuals were considered rare in the sampling, as suggested by Martins (1991). Significant differences between the two sampled areas were tested for richness from the Mann-Whitney U test (w) and for abundance, basal area and average height from the t-test (t). In addition, differences were evaluated for the diversity index of Shannon-Wiener by the test of Hutcheson and floristic composition by Non-Metric Multidimensional Scheduling (NMDS), following the ANOSIM test, using the Jaccard index. Posteriorly, differences in the proportion of dispersion syndromes and ecological groups per individual between the areas were evaluated by the chi-square test (Magurran 2004; Vieira 2008; Zar 2010). Before each analysis ($\alpha < 0.05$), a Shapiro-Wilk test was performed to test the normality of the data. With the exception of the Hutcheson t-test, performed with the Past software 2.17 (Hammer et al. 2013), all other tests were performed with the software R (R Development Core Team 2013).

## Results

### Richness, composition and abundance

In total, 1,783 individuals were sampled of which 804 were in the Forest area and 979 were in the eucalyptus area. The values of abundance between the plots of the forest area and eucalypt were significantly different ($t = -2.6768$; $p<0.05$). There were 102 dead individuals distributed between the two areas, with most of the deaths recorded (66 individuals) in the forest area. There were 84 species of living organisms from 67 genera. The areas showed a significant difference in the species richness ($w = 87.5$, $p < 0.01$), with 61 in the eucalyptus area and 65 in the Forest area; only 40 species were common to both areas (Table 1).

The Shannon-Wiener diversity index for the total area was low (H'= 3.35 nats/individual) and the general equitability was $J = 0.74$. It should be noted that the values between the analyzed areas showed a significant difference for H' ($t = -11.587$; $p < 0.01$), with the highest diversity value for the forest area (forest = 3.47, eucalypt = 2.84). Equitability was also higher in the forest area (forest = 0.83; eucalypt = 0.69).

The species presented a different abundance among the compared areas. The following species were observed in the Forest area: *Allophylus edulis* (n = 72), *Chomelia obtusa* (n = 68), *Cupania impressinervia* (n = 59) and *Myrcia splendens* (n = 48). More individuals of the following species were recorded in the sub-forest of eucalypt: *Genipa americana* (n = 189), *A. edulis* (n = 122), *Tapirira guianensis* (n = 121) and *C. obtusa* (n = 111) (Fig. 2; Table 1). The following rare species (i.e., with only

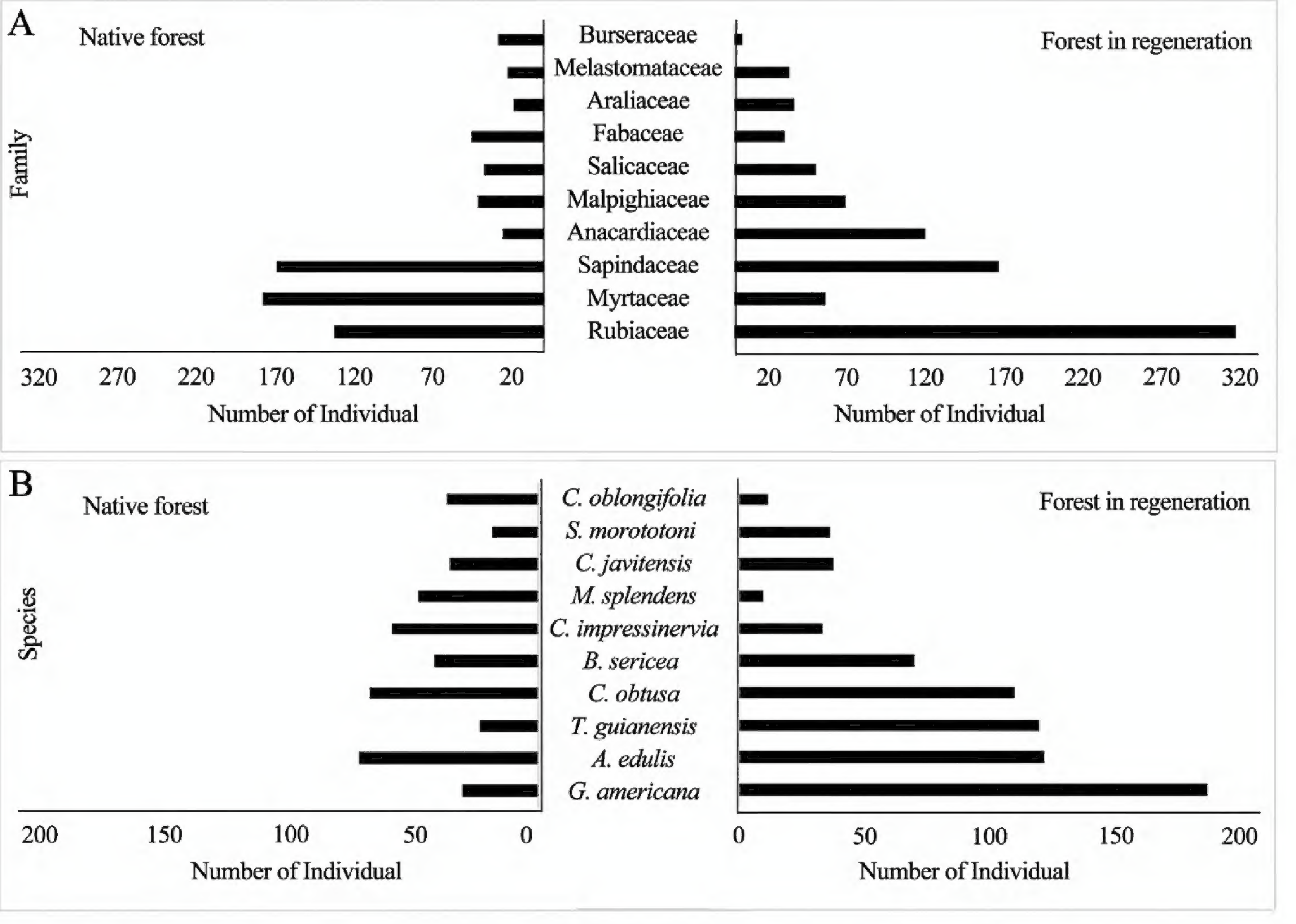


**Figure 2.** Distribution of family and species according to the number of individuals sampled in the two areas analyzed in the National Forest of Ibura, Sergipe, northeastern Brazil.

one individual) were collected in the forest area: *Actinostemon verticillatus, Clusia nemorosa, Eugenia schottiana, Swartzia dipetala* and *Vismia guianensis*. More rare species were recorded in the eucalyptus area (16 rare species) (Table 1).

Of the 60 woody species that settled in the sub-forest of the eucalyptus area, 19 did not occur in the forest area. In addition to the formation of two distinct groups (Fig. 3), significant differences ($r = 0.18$, $p < 0.01$) were observed for the floristic composition between the forest and eucalyptus areas.

The analysis of the ecological groups by individual between the areas showed a predominance of initial secondary individuals (ES: 422 ind.; PI: 283 ind.; LS: 96 ind.) in the forest area, while the regenerating area (eucalypt) had a predominance of pioneers (PI: 706 ind.; ES: 238 ind.; LS: 25 ind.) (Table 1). These differences were statistically significant ($x^2 = 29.33$; $p < 0.01$).

## Phytosociological parameters

The total basal area is 21.19 m$^2$/ha, and the results are similar when individualized between the analyzed areas (forest = 9.34 m$^2$/ha; eucalypt = 11.85 m$^2$/ha). It should be noted that the basal area value of the eucalyptus area is influenced by the high DBH value of *Corymbia citriodora*. In the same analysis performed without the presence of *C. citriodora*, the eucalypt forest presents a total basal area of 8.01 m$^2$/ha.

**Table 1.** List of living individuals by order of IV of the forest area, recorded in the phytosociological study of the shrub-arboreal stratum of the Ibura National Forest, Nossa Senhora do Socorro, Sergipe, northeastern Brazil. Legends: *= new occurrences in Sergipe (Santana et al. 2017); AB= abundance; DoR= relative dominance; DR= relative density; EG = ecological group: IS= initial secondary species, LS= late secondary species, PI= pioneer species; FR= relative frequency; IV= importance value index; NATIVE= Native Forest; NC= no characterization; Regeneration = Forest Regeneration.

| Species | EG | Native Forest | Ab | | DR | | FR | | DoR | | IV |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Regeneration | Native Forest | Regeneration | Native Forest | Regeneration | Native Forest | Regeneration | Native Forest | Regeneration |
| *Allophylus edulis* (A. St.-Hil.. Cambess. & A. Juss.) Radlk. | PI | 72 | 123 | 8.77 | 12.28 | 3.67 | 5.07 | 8.53 | 4.81 | 6.99 | 7.39 |
| *Tapirira guianensis* Aubl. | PI | 24 | 121 | 2.92 | 12.08 | 3.67 | 4.56 | 13.25 | 6.04 | 6.61 | 7.56 |
| *Byrsonima sericea* DC. | PI | 42 | 71 | 5.11 | 7.09 | 3.67 | 4.56 | 10.45 | 6.01 | 6.41 | 5.89 |
| *Cupania impressinervia* Acev.-Rodr. | IS | 59 | 34 | 7.18 | 3.39 | 4.08 | 4.06 | 4.06 | 1.66 | 5.11 | 3.04 |
| *Chomelia obtusa* Cham. &Schltdl. | PI | 68 | 111 | 8.28 | 11.08 | 4.08 | 5.07 | 1.54 | 2.21 | 4.63 | 6.12 |
| *Cupania oblongifolia* Mart.* | IS | 37 | 12 | 4.50 | 1.19 | 4.08 | 3.55 | 2.42 | 0.45 | 3.67 | 1.73 |
| *Myrcia splendens* (Sw.) DC. | IS | 48 | 10 | 5.84 | 0.99 | 2.04 | 1.52 | 1.49 | 0.16 | 3.12 | 0.89 |
| *Casearia javitensis* Kunth | IS | 36 | 38 | 4.38 | 3.79 | 2.85 | 3.55 | 1.45 | 0.85 | 2.89 | 2.73 |
| *Eugenia punicifolia* Kunth. | IS | 20 | 1 | 2.43 | 0.10 | 2.85 | 0.50 | 2.95 | 0.01 | 2.74 | 0.20 |
| *Campomanesia aromatic* (Aubl.) Griseb. | IS | 25 | 20 | 3.04 | 1.99 | 2.44 | 4.06 | 2.49 | 1.34 | 2.66 | 2.46 |
| *Genipa americana* L. | PI | 31 | 189 | 3.77 | 18.88 | 2.04 | 5.07 | 1.98 | 8.80 | 2.60 | 10.92 |
| *Protium heptaphyllum* (Aublet) Marchand | IS | 29 | 5 | 3.53 | 0.50 | 2.44 | 1.52 | 1.56 | 0.26 | 2.51 | 0.76 |
| *Campomanesia ilhoensis* Mattos | IS | 32 | 3 | 3.89 | 0.30 | 2.04 | 1.01 | 1.41 | 0.12 | 2.45 | 0.47 |
| *Miconia albicans* (Sw.) Triana | IS | 23 | 35 | 2.80 | 3.49 | 3.67 | 3.04 | 0.84 | 0.59 | 2.44 | 2.38 |
| *Randia armata* (Sw.) DC. | IS | 25 | 19 | 3.04 | 1.89 | 2.85 | 3.04 | 1.35 | 0.42 | 2.41 | 1.78 |
| *Eschweilera ovata* (Cambess.) Miers. | LS | 17 | 2 | 2.07 | 0.20 | 2.04 | 1.01 | 2.74 | 0.03 | 2.28 | 0.41 |
| *Paubrasilia echinata* (Lam.) E. Gagnon. H. C. Lima & G. P. Lewis.* | LS | 9 | 0 | 1.09 | | 0.81 | 0 | 4.79 | 0 | 2.23 | 0 |
| *Ocotea glomerata* (Nees) Mez | LS | 21 | 2 | 2.55 | 0.20 | 2.85 | 1.01 | 0.84 | 0.04 | 2.08 | 0.42 |
| *Schefflera morototoni* (Aubl.) Maguire. Steyerm. & Frodin | PI | 19 | 37 | 2.31 | 3.69 | 2.04 | 4.06 | 1.81 | 1.15 | 2.05 | 2.96 |
| *Sorocea hilarii* Gaudich.* | IS | 11 | 3 | 1.34 | 0.30 | 2.04 | 1.52 | 2.60 | 0.03 | 1.99 | 0.61 |
| *Cassia grandis* L. f. | LS | 9 | 0 | 1.09 | | 0.81 | 0 | 3.12 | 0 | 1.68 | 0 |
| *Campomanesia dichotoma* (O.Berg) Mattos | LS | 13 | 1 | 1.58 | 0.10 | 2.44 | 0.50 | 0.94 | 0.008 | 1.65 | 0.20 |
| *Machaerium hirtum* (Vell.) Stellfeld | IS | 7 | 7 | 0.85 | 0.69 | 1.63 | 0.50 | 1.93 | 0.60 | 1.47 | 0.60 |
| *Cecropia pachystachya* Trécul | PI | 5 | 13 | 0.60 | 1.29 | 1.63 | 2.53 | 2.10 | 3.13 | 1.44 | 2.32 |

| Species | EG | Native Forest | Ab | | DR | | FR | | DoR | | IV |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Regeneration | Native Forest | Regeneration | Native Forest | Regeneration | Native Forest | Regeneration | Native Forest | Regeneration |
| *Psidium decussatum* DC. | IS | 11 | 0 | 1.34 | 0 | 2.04 | 0 | 0.72 | 0 | 1.36 | 0 |
| *Chomelia pubescens* Cham. & Schltdl* | IS | 10 | 0 | 1.21 | 0 | 2.04 | 0 | 0.67 | 0 | 1.31 | 0 |
| *Sparattanthelium batocudorum* Mart. | IS | 8 | 9 | 0.97 | 0.89 | 2.04 | 3.04 | 0.30 | 0.15 | 1.10 | 1.36 |
| *Hymenaea courbaril* L. | PI | 2 | 0 | 0.24 | 0 | 0.81 | 0 | 2.13 | 0 | 1.06 | 0 |
| *Eugenia brejoensis* Mazine | LS | 9 | 0 | 1.09 | 0 | 1.22 | 0 | 0.57 | 0 | 0.96 | 0 |
| *Libidibia férrea* (Mart. exTul.) L.P.Queiroz | LS | 4 | 0 | 0.48 | 0 | 0.40 | 0 | 1.96 | 0 | 0.95 | 0 |
| *Inga capitata* Desv. | IS | 6 | 0 | 0.73 | 0 | 1.63 | 0 | 0.12 | 0 | 0.83 | 0 |
| *Eugenia* sp. | NC | 4 | 0 | 0.48 | 0 | 1.63 | 0 | 0.29 | 0 | 0.80 | 0 |
| *Schoepfia brasiliensis* A.DC. | IS | 7 | 3 | 0.85 | 0.300 | 1.22 | 1.01 | 0.23 | 0.11 | 0.77 | 0.47 |
| *Eugenia candolleana* DC. | IS | 6 | 1 | 0.73 | 0.100 | 1.22 | 0.50 | 0.30 | 0.02 | 0.75 | 0.21 |
| *Psidium oligospermum* Mart. ex DC. | NC | 4 | 0 | 0.48 | 0.000 | 1.63 | 0 | 0.05 | 0 | 0.72 | 0 |
| Undetermined | NC | 4 | 1 | 0.48 | 0.100 | 1.22 | 0.50 | 0.36 | 0.01 | 0.69 | 0.20 |
| *Licania rigida* Benth.* | PI | 2 | 4 | 0.24 | 0.400 | 0.81 | 1.52 | 1.00 | 0.11 | 0.68 | 0.67 |
| *Brosimum guianense* (Aubl.) Huber | LS | 3 | 0 | 0.36 | 0 | 0.81 | 0 | 0.87 | 0 | 0.68 | 0 |
| *Cordia taguahyensis* Vell. | IS | 3 | 0 | 0.36 | 0 | 1.22 | 0 | 0.09 | 0 | 0.56 | 0 |
| *Cordia toqueve* Aubl. | LS | 2 | 9 | 0.24 | 0.899 | 0.81 | 1.52 | 0.46 | 0.64 | 0.50 | 1.02 |
| *Vitex rufescens* A.Juss. | LS | 2 | 0 | 0.24 | 0 | 0.81 | 0 | 0.27 | 0 | 0.44 | 0 |
| *Apeiba tibourbou* Aubl. | PI | 2 | 1 | 0.24 | 0.100 | 0.81 | 0.50 | 0.17 | 0.20 | 0.41 | 0.27 |
| *Annona montana* Macfad. | IS | 2 | 0 | 0.24 | 0 | 0.81 | 0 | 0.15 | 0 | 0.40 | 0 |
| *Bauhinia* sp. | IS | 2 | 0 | 0.24 | 0 | 0.81 | 0 | 0.09 | 0 | 0.38 | 0 |
| *Diospyru sinconstans* Jacq.* | IS | 2 | 0 | 0.24 | 0 | 0.81 | 0 | 0.07 | 0 | 0.37 | 0 |
| *Swartzia acutifolia* Vogel* | LS | 2 | 0 | 0.24 | 0 | 0.40 | 0 | 0.47 | 0 | 0.37 | 0 |
| *Psidium oligospermum* Mart. ex DC. | LS | 2 | 0 | 0.24 | 0 | 0.81 | 0 | 0.05 | 0 | 0.37 | 0 |
| *Tabernaemontana* sp. | NC | 2 | 1 | 0.24 | 0.100 | 0.81 | 0.50 | 0.05 | 0.16 | 0.37 | 0.25 |
| *Mangifera indica* L. | LS | 2 | 1 | 0.24 | 0.100 | 0.40 | 0.50 | 0.43 | 0.36 | 0.36 | 0.32 |
| Fabaceae sp. 1 | LS | 1 | 0 | 0.12 | 0 | 0.40 | 0 | 0.53 | 0 | 0.35 | 0 |
| Fabaceae sp. 2 | NC | 1 | 0 | 0.12 | 0 | 0.40 | 0 | 0.28 | 0 | 0.27 | 0 |
| *Bowdichia virgilioides* Kunth. | LS | 1 | 6 | 0.12 | 0.599 | 0.40 | 2.03 | 0.25 | 1.41 | 0.26 | 1.34 |
| *Swartzia dipétala* Willd. Ex Vogel* | LS | 1 | 0 | 0.12 | 0 | 0.40 | 0 | 0.19 | 0 | 0.24 | 0 |
| *Casearia sylvestris* Sw. | IS | 2 | 13 | 0.24 | 1.299 | 0.40 | 2.03 | 0.06 | 0.43 | 0.23 | 1.25 |
| *Myrcia tomentosa* (Aubl.) DC. | IS | 2 | 1 | 0.24 | 0.100 | 0.40 | 0.50 | 0.04 | 0.01 | 0.23 | 0.20 |
| *Allophylus racemosus* Sw.* | IS | 2 | 0 | 0.24 | 0 | 0.40 | 0 | 0.03 | 0 | 0.23 | 0 |
| Fabaceae sp. 2 | NC | 1 | 4 | 0.12 | 0.400 | 0.40 | 0.50 | 0.13 | 0.73 | 0.22 | 0.54 |

| Species | EG | Native Forest | Ab | | DR | | FR | | DoR | | IV |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Regeneration | Native Forest | Regeneration | Native Forest | Regeneration | Native Forest | Regeneration | Native Forest | Regeneration |
| *Vismia guianensis* (Aubl.) Pers. | PI | 1 | 0 | 0.12 | 0 | 0.40 | 0 | 0.03 | 0 | 0.18 | 0 |
| *Ziziphus joazeiro* Mart. | IS | 1 | 6 | 0.12 | 0.599 | 0.40 | 1.52 | 0.03 | 0.35 | 0.18 | 0.82 |
| *Cynophalla flexuosa* (L.) J. Presl | IS | 1 | 5 | 0.12 | 0.500 | 0.40 | 1.01 | 0.03 | 0.22 | 0.18 | 0.57 |
| *Clusia nemorosa* G.Mey. | LS | 1 | 0 | 0.12 | 0 | 0.40 | 0 | 0.02 | 0 | 0.18 | 0 |
| *Myrcia* sp. 1 | LS | 1 | 1 | 0.12 | 0.100 | 0.40 | 0.50 | 0.01 | 0.007 | 0.18 | 0.20 |
| *Actinostemon verticillatus* (Klotsch) Baill | LS | 1 | 0 | 0.12 | 0 | 0.40 | 0 | 0.01 | 0 | 0.18 | 0 |
| *Myrciaria* sp. 1 | LS | 1 | 1 | 0.12 | 0.100 | 0.40 | 0.50 | 0.009 | 0.06 | 0.18 | 0.22 |
| *Eugenia schottiana* O. Berg | IS | 1 | 1 | 0.12 | 0.100 | 0.40 | 0.50 | 0.009 | 0.11 | 0.18 | 0.23 |
| *Adenanthera pavonina* L. | LS | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.05 | 0 | 0.21 |
| *Anadenanthera peregrina* (L.) Speg. | LS | 0 | 2 | 0 | 0.200 | 0 | 0.50 | 0 | 2.54 | 0 | 1.08 |
| *Clitoria fairchildiana* R.A. Howard | PI | 0 | 11 | 0 | 1.099 | 0 | 1.52 | 0 | 5.03 | 0 | 2.55 |
| *Didymopanax* sp. | IS | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.01 | 0 | 0.20 |
| *Entrolobium* sp. | NC | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.41 | 0 | 0.34 |
| *Erythroxylum citrifolium* A. St. – Hil | IS | 0 | 2 | 0 | 0.200 | 0 | 1.01 | 0 | 0.01 | 0 | 0.41 |
| *Corymbia citriodora* (Hook.) K.D.Hill & L.A.S.Johnson | NC | 0 | 16 | 0 | 1.598 | 0 | 3.55 | 0 | 28.12 | 0 | 11.03 |
| *Ficus* sp. | PI | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 4.34 | 0 | 1.65 |
| Lamiaceae sp. | NC | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.05 | 0 | 0.21 |
| *Maclura tinctoria* (L.) D. Donex Steud.* | PI | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.02 | 0 | 0.21 |
| *Marlierea excoriata* Mart. | PI | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.01 | 0 | 0.20 |
| *Piper amalago* L.* | IS | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.01 | 0 | 0.20 |
| *Prockia crucis* P. Browne ex L. | PI | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.01 | 0 | 0.20 |
| *Psidium guineense* Sw. | PI | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.03 | 0 | 0.21 |
| *Averrhoidium gardnerianum* Baill. | NC | 0 | 6 | 0 | 0.599 | 0 | 1.01 | 0 | 0.21 | 0 | 0.60 |
| *Sideroxylon obtusifolium* (Roem & Schutt) Penn. | IS | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.01 | 0 | 0.20 |
| *Tocoyena formosa* (Cham. &Schltdl.) K. Schum. | PI | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.02 | 0 | 0.20 |
| *Xylopia frutescens* Aubl. | IS | 0 | 4 | 0 | 0.400 | 0 | 1.01 | 0 | 0.12 | 0 | 0.51 |
| *Zanthoxylum unifoliolatum* Groppo & Pirani * | IS | 0 | 1 | 0 | 0.100 | 0 | 0.50 | 0 | 0.06 | 0 | 0.22 |

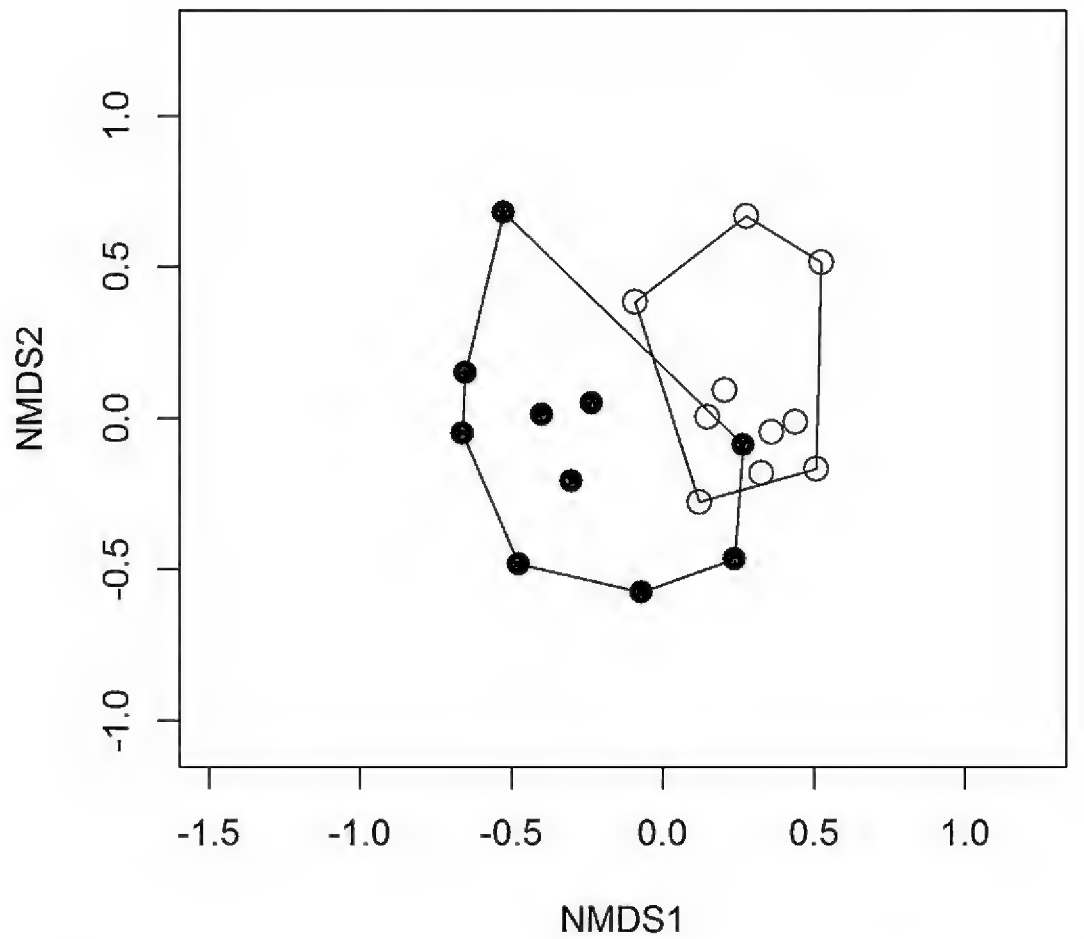


**Figure 3.** Distribution of plots in the forest area (●) and in the eucalypt area (○), both located in the National Forest of Ibura, in the state of Sergipe, northeastern Brazil, obtained by Non-Metric Multidimensional Scheduling (NMDS) based on the Jaccard index. Stress value = 0.16.

The statistical analysis performed without the presence of *C. citriodora* revealed no significant differences ($t = 0.32$; $p > 0.05$) between the areas.

The species with the highest relative densities in the forest area were *A. edulis* (8.76 ind./ha), *C. obtusa* (8.28 ind./ha) and *C. impressinervia* (7.18 ind./ha). In the area of eucalypt, *G. americana* (18.8 ind./ha), *A. edulis* (12.28 ind./ha) and *T. guianensis* (12.8 ind./ha) showed the highest relative densities.

As for relative dominance, the forest values appear in the following order: *Tapirira guianensis* (14.63 $m^2$/ha), *Byrsonima sericea* (11.53 $m^2$/ha) and *Allophylus edulis* (9.42 $m^2$/ha). In the area of eucalypt, the most important species for dominance were *Corymbia citriodora* (32.36 $m^2$/ha), *G. americana* (10.13 $m^2$/ha) and *Tapirira guianensis* (6.96 $m^2$/ha) e *B. sericea* (6.91 $m^2$/ha) (Fig. 4; Table 1). The high basal area of *C. citriodora*, *Clitoria fairchildiana* and *Paubrasilia echinata* contributed to the dominance values of these species. The *Ficus* sp. (Moraceae) is also worth mentioning because it ranks among the eight species with the greatest dominance, even though only one sample was recorded (Table 1).

For the results of the importance value, a small variation was found between species in the two areas analyzed, the important forest (VI) species included *A. edulis* (6.99%), *T. guianensis* (6.61%), *B. sericea* (6.41%) and *Cupania impressinervia* (5.11%). The important species in the eucalyptus area included *C. citriodora* (11.09%), *G. americana* (10.92%), *T. guianensis* (7.56%) and *A. edulis* (7.39%) (Table 1).

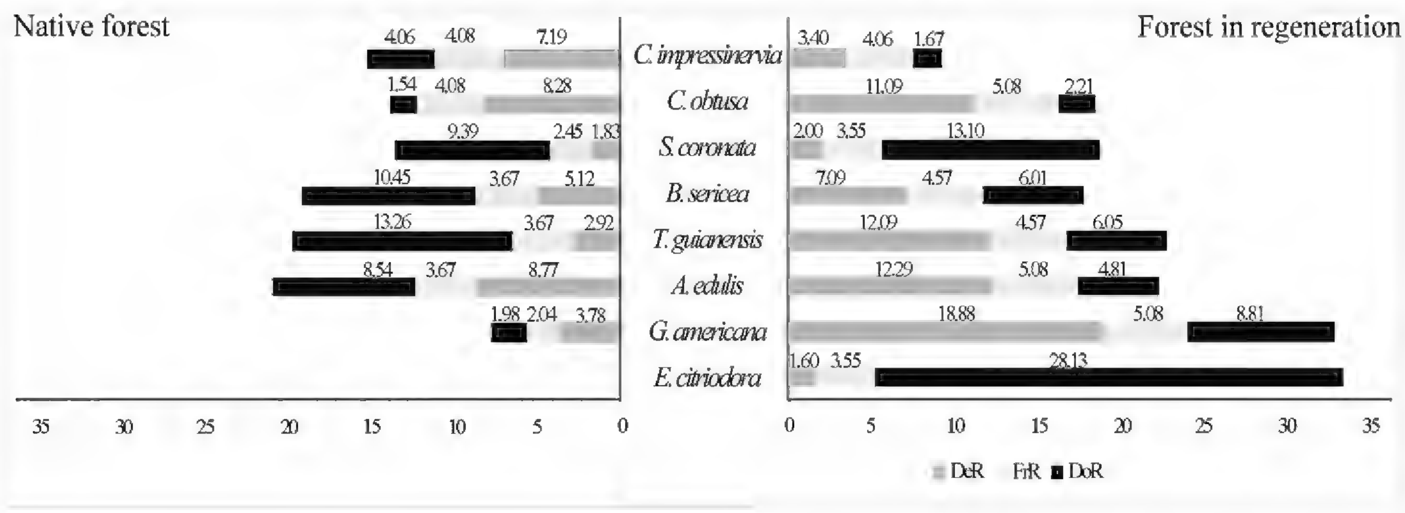


**Figure 4.** Distribution of species according to relative density, relative frequency, relative dominance, sampled in the analyzed areas of the phytosociological study in the National Forest of Ibura, Sergipe, northeastern Brazil.

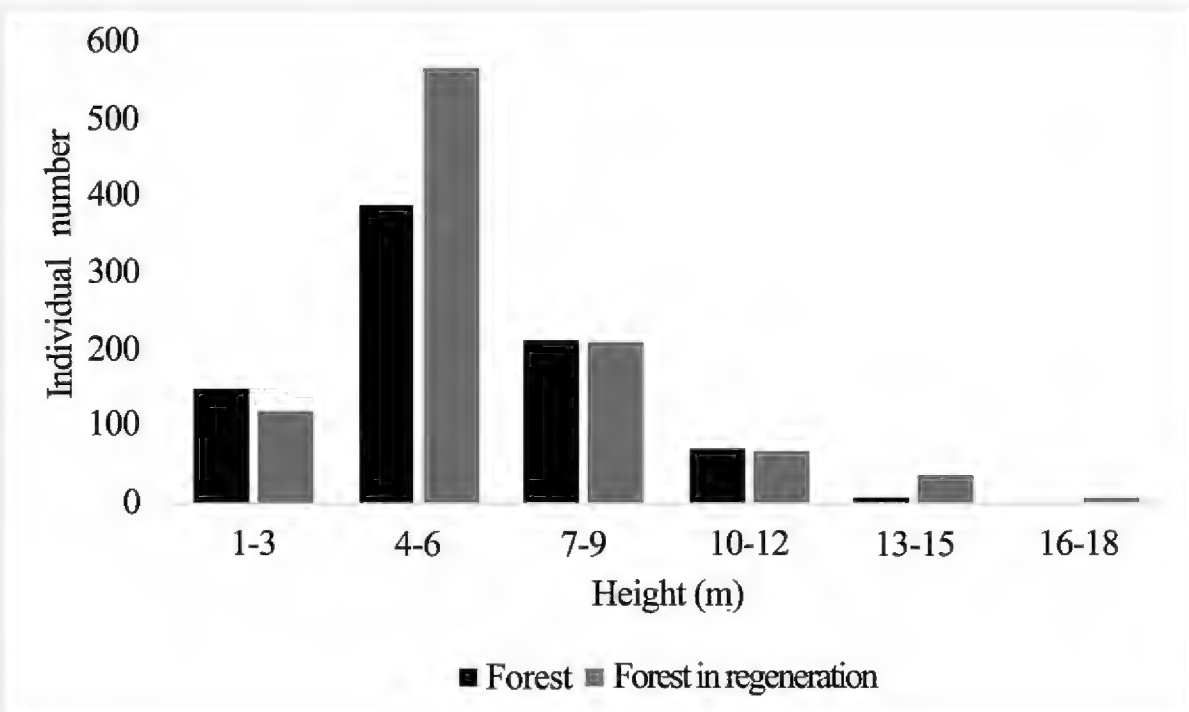


**Figure 5.** Frequency distribution of height classes (m) of the individuals sampled in the two areas analyzed in the phytosociological study of the Ibura National Forest, Sergipe, northeastern Brazil.

The eight species with the highest importance value in the forest area represent 41% of the total VI by species and 44% of the total of individuals for this area. For the eucalyptus area, the eight species accounted for 58% of the total VI per species and 68% of the total for this area. *Corymbia citriodora* had lower abundance in the eucalyptus area but were among the most important species.

The heights within the plots varied between 1.30 and 18.0 meters, with the majority of individuals presenting between 4 and 9 m in height. The eucalyptus area presented the majority of individuals between 4 and 6 m, although it was similar to the forest area in the other height classes (Fig. 5). Although the forest area contained individuals with a higher mean height than those in the eucalyptus area, there was not a

significant difference in average heights of the taller species, such as *C. pachystachya*, *Protium heptaphyllum*, *Tapirira guianensis* and *Byrsonima sericea* ($t = 0.44$; $p > 0.05$).

## Discussion

The highest abundance observed for the eucalyptus area resulted from the presence of many young regenerating individuals and/or those of low diameter values. Some of these fine individuals belong to pioneer species, typically found in areas under regeneration, presenting rapid growth and low longevity, which justifies their high abundance in the eucalyptus area, subsidizing the observed difference between areas (Budowski 1965). Similar results are also characteristic of other areas of Atlantic Forest, and vegetation may behave as a community-stock, where individuals are emerging for forest renewal (Scolforo 1998; Abreu et al. 2013; Souza et al. 2012).

The eucalyptus area presented lower species richness compared to other areas of natural remnants (Lindenmayer and Hobbs 2004; Barlow et al. 2007). In addition, it was observed that the eucalyptus area has not yet fully recovered from deforestation of 35 years ago in relation to the parameters of richness and Shannon-Wiener diversity. The speed of recovery of these parameters in the regenerated areas in the eucalypt sub-forest has been associated with the proximity of a source of propagules and the maintenance of the seed bank (Calegario et al.1993; Onofre et al. 2010). In some cases, even after 20 years of regeneration, values of Shannon-Wiener diversity and Pielou equitability between natural remnants and eucalypt regeneration areas are still not the same (Nóbrega et al. 2008). Considering that the areas of forest and eucalypt are contiguous in the Ibura FLONA, it is believed that other factors may have interfered (e.g., time needed for the populations to settle in the site) in the recovery of the species richness and of the Shannon-Wiener diversity in the eucalyptus area. This index gives greater weight to abundance. Equitability was low in the eucalyptus area, showing that abundance is poorly distributed among species. Thus, this low relative proportion of species abundances may indicate that rare species have difficulties settling in the eucalyptus area.

The overall value of the Shannon-Wiener index for the Ibura FLONA was considered low. For the Atlantic Forest, values are commonly found between 3.16 and 4.29 nats/individuals, as reviewed by Martins (1991) and Leitão-Filho (1987). However, it is known that the value of Shannon-Wiener diversity can reach up to 5.71 nats/individuals in tropical forests (Knight 1975). It is probable that anthropization processes, usually observed in the Ibura FLONA, could have influenced the diversity values.

At least two of the four families with the highest specific richness in this study were also predominant, sometimes reversing the order of importance, in phytosociological studies carried out in other fragments or ecosystems associated with the Sergipe Forest Atlantic (e.g., Dantas et al. 2010; Oliveira et al. 2013) and in Northeastern Brazil (e.g., Tavares et al. 2000; Andrade and Rodal 2004; Brandão et al. 2009).

From the analysis of the ecological groups, it was observed that the Ibura FLONA has not yet reached the climax stage, mainly the eucalyptus area, represented in

great part by pioneer individuals. In turn, the forest area, even presenting a more advanced age and structure, is not yet characterized by mature vegetation. A high prevalence of pioneer individuals was also observed by Evaristo et al. (2011) in a regenerated area of eucalypt abandoned 12 years ago in the state of Rio de Janeiro. In the initial stages of succession, the predominance of pioneer individuals in the areas undergoing eucalypt regeneration has been associated with the presence of high luminosity in the sub-forest, considering that these conditions may not favor the establishment of early secondary species and climax species (Tabarelli et al. 1993). However, along the successional process, the pioneer species promote shading on late secondary species, which may contribute to the natural regeneration of this group (see Gandolfi et al. 1995 for a discussion of ecological groups).

The characterization of the eucalyptus area at a more initial successional stage than the forest area indicates that the successional processes in the 35 year period are insufficient for the Atlantic Forest areas to reach the climax stage. The evolution of these processes is dependent on internal factors (reproductive rate, colonization, competitive success) and external factors (distance between fragment, dispersion between area, low anthropic pressure) (Carmo and Assis 2012). In addition, any continuous action or influence that limits the natural functioning of the environments can cause a constant energy wear on the species, thus making it difficult for these ecosystems, and the species, to reach their maximum stage in the levels of ecological succession (Lugo and Snedaker 1974). This fact occurs mainly in areas that have undergone anthropic disturbance, thus presenting low Shannon-Wiener values, less richness and reflecting a more homogeneous composition (Nappo et al. 2004).

The estimated total basal area value for the Ibura FLONA was considered intermediate when compared to some studies carried out for areas of Atlantic Forest of Sergipe and Northeastern Brazil (ranging from 12.06 to 44.40 $m^2$/ha; Tavares et al. 2000; Andrade and Rodal 2004; Brandão et al. 2009). Disregarding the individuals of *Corymbia citriodora*, the values of basal area were similar between the analyzed areas, with a small difference. These results show that the basal area is one of the first parameters to be recovered in stands, but with a relevant contribution of individuals of smaller diameter, abundant in the regenerated areas.

In turn, low density species should have limitations for their population growth. It is possible that the selective cut in the area to groups of species considered rare may also limit the population growth of some species. In addition, environmental characteristics that are subject to different types of tensors should be considered as an influence to the structural development of forests and the colonization of species in deforested areas (Lugo and Snedaker 1974) and influenced by the presence of *Corymbia citriodora*.

The species of highest value of importance (IVI) in the forest area are still the most important in relation to the other phytosociological indexes of this study, mainly the values of density and relative dominance. The *Chomelia obtusa* showed high values of density and frequency, but with low dominance, showing the high colonization capacity and making it a good local competitor. The presence of

*C. obtusa* in open sites and tracks in the Ibura FLONA may indicate that individuals of this species prefer to colonize areas of high luminosity. This fact may explain the higher abundance value for the eucalyptus area.

Several approaches suggest the use of eucalypt species (*Eucalyptus* spp. and *Corymbia citriodora*) for the recovery of forest areas (Sartori et al. 2002). Although eucalypt is indicated as a facilitating species, additional studies are required to investigate the precise contribution of this exotic species to natural regeneration. This fact is reinforced in this study, where it was shown that not all native species were able to settle in the eucalyptus area, which subsidized the significant differences observed in the floristic composition and the formation of two distinct groups between this area and that of the forest. About 80% of native species occurring in the forest area, but not in the eucalyptus area, are late secondary species (Table 1). Eucalypt may limit the presence of some groups of late secondary species, which presented lower frequency in the analyzed eucalyptus area.

Finally, it was concluded that the period of 35 years was not sufficient for the recovery of the abandoned area with established planting of eucalyptus. But the eucalyptus plantation favored the arrival of the most common species in the forest area, while many species considered to be rare, as well as late secondary successional species were limited to this forest area. We recommend caution and planning in the use of this exotic homogeneous species. Priority should be given to the planting of native species with high colonization capacity in the recovery of degraded areas.

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